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COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Manned Space Flight Systems--
Classification of Hazards and
Safety Measures

TM- 68-2033-1

DATE-December 20, 1968

FILING CASE NO(S)- 320

AUTHOR(S)- J. D. Richey

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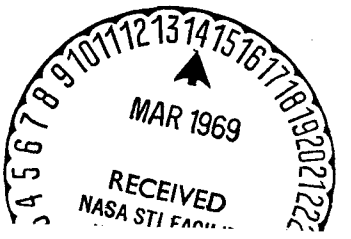
ABSTRACT

A model of a manned space flight emergency is developed and used to categorize hazardous conditions or events identified in five representative space flight safety studies. Potential users of checklists based on the defined hazards categories are suggested. Safety measures, preventive and remedial, are briefly discussed.



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TECHNICAL MEMORANDUM

INTRODUCTION

Methodic approaches to safety on large complex programs usually require a systematic identification of hazards as a first step toward their avoidance or control. For this purpose, hazards are defined as undesirable conditions or events that threaten the integrity of equipment and/or the well being of associated personnel.

As part of recent safety studies, a number of workers and organizations in the aerospace community have prepared lists of conditions or events that may threaten safety on manned space programs. Comparison of five such efforts suggests that there are areas of agreement (overlap), differences in emphasis, and voids in coverage among the lists. The listings range from improper design or training, through explosion or fire, to an inability to ascend from the lunar surface. The nature of each list appears to reflect the background and philosophy of the lister and the purpose for which the list was generated.

In an effort to understand and relate the various items identified in the lists, a model of a space flight emergency was developed by considering a mission sequence. Based on the developed mission sequence a set of categories of hazards (and related mission events) was defined. These categories were then "seeded" with the items identified in the five selected aerospace safety efforts. Finally, the model of a space flight emergency was used to define classes of safety measures. In the process of modeling a manned space flight emergency, models of a generalized systems emergency and a test or simulation emergency were also defined.

If the approach to hazards classification described herein proves valid, it could be used as a starting point for generation of working checklists that could be useful to various program elements for improving flight safety in a manned aerospace program.

OBJECTIVE

The objective of the effort was to identify suitable hazards categories for manned space flight programs and to begin compilation of checklists that would be of interest and assistance to the elements and organizations that address safety on large space programs. The program elements considered were: (1) Agency Management, (2) Program Management, (3) Space Vehicle Design, (4) Stage or Module Design, (5) System Design, (6) Component Design, (7) Mission Planning, and (8) Safety Engineering. Descriptive statements for these elements will be found in Attachment A. The utility of the checklists may vary as the program progresses from the inception phase, through design, manufacture, and test, to operational usage.

MANNED SPACE FLIGHT EMERGENCY

Although our interest is manned space flight emergencies, it is useful to first consider a model of a generalized system emergency. The life cycle of a system can be considered to have two phases; the pre-operational period, which includes design and manufacture, and the operational period. These phases are identified on the block diagram model of a generalized system emergency which is shown in Figure 1. System emergencies occur in the operational period and begin with some initial impairment. The initial impairment (trigger) is caused either by an operational risk (usually unavoidable), or by a pre-operational period cause (usually preventable) that can be traced to an act of omission or commission in the pre-operational period. The initial failure may propagate and can result in a system degradation. The severity of the resulting situation depends on the system functions involved and the extent to which they are degraded. The degraded system could have some residual capability but might later suffer further initial impairment-propagation cycles. Operation of the system at its reduced capability will lead to a lower resulting system performance. In the case of manned systems the operating personnel are a part of the system and may be impaired in the course of an emergency.

With minor word changes Figure 1 can be tailored to represent the corresponding elements of a manned space flight emergency. In Figure 2 each element block has been expanded to show, in the context of Apollo technology, the types of events, conditions, or capabilities that are covered by each element.

A space flight emergency is considered to begin with an Initial Impairment (Trigger) which can be: (1) a component failure, (2) a crew or ground personnel error, or (3) a crew

impairment. These impairments, most likely minor in themselves, are traceable either to Mission Period Risks or to Pre-Mission Period Causes of the types indicated. Once it has occurred, an Initial Impairment may be contained or propagated in various fashions to adversely affect the crew and equipment. In time, propagation of the Initial Impairment will stop or become stabilized. The effects on the system can be described in terms of the State of Crew and Equipment, which in turn will determine the subsequent Mission Progression. The nature of the Mission Progression will establish the End Result of the mission. Subsequent (initial) impairments could cycle through the system with further system degradation and less favorable end results. Those items which fall under Mission Period Risks, Pre-Mission Period Causes and Propagation are aptly termed hazards as they either bring about the initial impairment or cause it to expand into a situation that threatens the mission.

An Initial Impairment is not considered a hazard but is an event which can result from hazards in the Mission Period Risk or Pre-Mission Period Causes categories. The State of Crew and Equipment is the result of an Initial Impairment and the action of Propagation hazards. Items in this category can best be described as emergencies. Mission Progression is the next step in the sequence. It is not categorized as a hazard.

The model of a generalized system emergency depicted in Figure 1 could be modified for use in programs or operations other than manned space flight. Figure 3 is a variation of Figure 1 tailored to the elements of manned test emergency. Figure 3 is provided as an example and is not developed further in this memorandum.

SPACE FLIGHT EMERGENCY STUDIES AND HAZARDS ANALYSES

As a test exercise, the set of categories defined in Figure 2 was used as a basis for the classification of sampling of hazards (and items not considered hazards herein) previously identified by others. For this purpose, documents developed by (1) the Rand Corporation, (2) the Aerospace Corporation, (3) the Teague Subcommittee on NASA Oversight of the Committee on Science and Astronautics, U. S. House of Representatives, (4) the United States Air Force, and (5) the General Electric Company, were selected as representative sources. The documents are fully identified in Attachment B, and the principal hazards and emergencies noted in each work are shown on Table 1. The documents had somewhat different objectives and placed emphasis on various aspects of space flight emergencies.

The Rand and Aerospace studies both examined ways of configuring a space system to reduce the risks of manned space

flight. The Rand report pointed out the three underlying threats to life: metabolic deprivation, excessive physiological stresses, and chemical or physical injury. Emergencies that could cause these threats, and systems which most effectively counteract the threats are noted. The Aerospace report is more specific than the Rand study with respect to equipment failures and also develops means of preventing and counteracting threats to the crewmen's lives.

The "Teague" report is a compilation and summary of replies to a questionnaire sent by the Teague Subcommittee on NASA Oversight to various industrial concerns and government agencies working in the aerospace field. The questionnaire asked for information on any studies that may have been performed relative to space flight emergencies. The responses to the questionnaire generally were concerned with means of counteracting specific emergencies. Many of these emergencies identified in the Teague report are similar to those noted in the Rand and Aerospace reports.

The Air Force and General Electric Company reports are essentially compilations of various hazards or emergencies that may threaten the lives of space flight crews. The Air Force Report was based on an extensive study of hazards, including causes and the portion of the operational sequence during which a given hazard is critical, and the components affected. The GE hazard report drew on the company's experience in Apollo reliability activities and the causes of some of the listed hazards, and included the components that are threatened by a given hazard.

As can be seen in Table 1, there were both similarities and differences among the five works with respect to the items that were identified as hazards or threats to the crew or equipment.

CLASSIFICATION OF HAZARDS

Table 2 is a listing of the items shown in Table 1 arranged to indicate the document that identified each item and the category or categories into which each item is believed to fall. Some items fall into the three hazards categories (Mission Period Risks, Pre-Mission Period Causes and Propagation) whereas others have been classified as Initial Impairment, State of Crew and Equipment and Mission Progression (four footnoted cases). In many cases, classification of a hazard in more than one category reflects uncertainty concerning the precise meaning of the terminology used by the identifier. The identified hazards are in some cases broad and inclusive and in other cases very narrow and specific.

Tables 3, 4, and 5 are examples of hazards checklists showing the hazards identified in Table 2 for each major hazards category. Entries are arranged according to subgroups shown in Figure 2. Where groups were vacant, typical hazards were supplied by the writer. Voids were most apparent in the Underlying Causes category. Elements of a manned space program (Appendix A) that might use each checklist are also noted.

Tables 6 and 7 are similar compilations of Initial Impairments and States of Crew and Equipment based on the information presented in Table 2.

The checklists (Tables 3-7) are not presented as complete. They could, however, provide a starting point for a more extensive hazard compilation effort.

SAFETY MEASURES

For many identified hazards there is, at least in theory, a means of preventing them. The means can be classed as a preventive safety measure. Other safety measures aimed at coping with emergencies, once they have occurred, are classed as remedial. Although the model of a manned space flight emergency (Figure 2) was developed as an aid to the classification of hazards, it also provides a basis for the classification of safety measures.

Figure 4 is a condensation of Figure 2 to which has been added a summary of types of Applicable Safety Measures. Preventive safety measures forestall hazards classed as Mission Risks, Underlying Causes and Propagation. Examples of preventive safety measures which reduce Mission Period Risks are: a) better analysis and distribution of existing data, b) new knowledge, data and understanding, and c) higher reliability goals. From the standpoint of the Apollo program, the Surveyor program was a safety measure which reduced Apollo mission risks by providing new knowledge, data and understanding of the lunar environment. Establishment and implementation of high reliability practices should reduce statistical probability of an "expected" mission failure.

The Pre-Mission Period Causes of an Initial Impairment are eliminated by effective implementation of a variety of good program practices and disciplines. Some of these are identified on Figure 4.

Propagation of an Initial Impairment may be limited by implementation of safety measures such as those indicated on Figure 4. For example, a complete loss of a spacecraft

function through propagation of an Initial Impairment could be avoided by the provision of a redundant capability for the function. Isolation, damage control, and detection capability impede or arrest the propagation of an Initial Impairment.

Two classes of remedial safety measures are shown on Figure 4. Repair and medical aid capabilities are the class of remedial safety measures which can be used to improve the state of degraded equipment or injured crew. After these remedial measures have been applied to the crew and equipment, the mission will progress as dictated by the remaining system capabilities and the second class of remedial measures that are available, including alternate mission modes, abort, escape,and rescue.

The five classes of safety measures suggested on Figure 4 could be used as the basis for an expanded catalogue of manned space flight safety measures.

SUMMARY

The point of view presented in this memorandum is that a manned space flight emergency is triggered by some (generally small) Initial Impairment. The Initial Impairment is caused either by a Mission Period Risk or a Pre-Mission Period Underlying Cause. Depending on circumstances, the Initial Impairment may or may not propagate and bring about a degraded state of the equipment and/or crew. Those conditions or events that can be classified as Mission Period Risks, Pre-Mission Period Causes, or Propagation (modes) are considered to be hazards. State of Crew and Equipment (following an Initial Impairment and Propagation) and subsequent Mission Progression are elements of a manned space flight emergency, which involve threats to crew safety, are not considered as hazards as such.

Prevention of an Initial Impairment and its Propagation should be the prime objectives of any safety program. This is achieved through adequate design, good manufacturing and test practices and by proper mission planning and selection and training of personnel. Remedial safety measures designed to improve the State of Crew and Equipment or to enable viable Mission Progression are back-up or auxillary capabilities used to extricate the mission and crew from a degraded or emergency state. It is clear that the adequacy of the preventive and remedial safety measures is directly related to the effectiveness of program management.

It is hoped that the views presented herein will stimulate thought, debate and perhaps a better understanding

of space flight hazards, emergencies and safety measures and in this manner assist those program elements, particularly program and safety, working to improve flight safety.

The contributions of Mr. G. B. Troussoff to this analysis is gratefully acknowledged.

J. D. Richey

2033-JDR-bah

Attachments
Figures 1-4
Tables 1-7
Attachments A and B

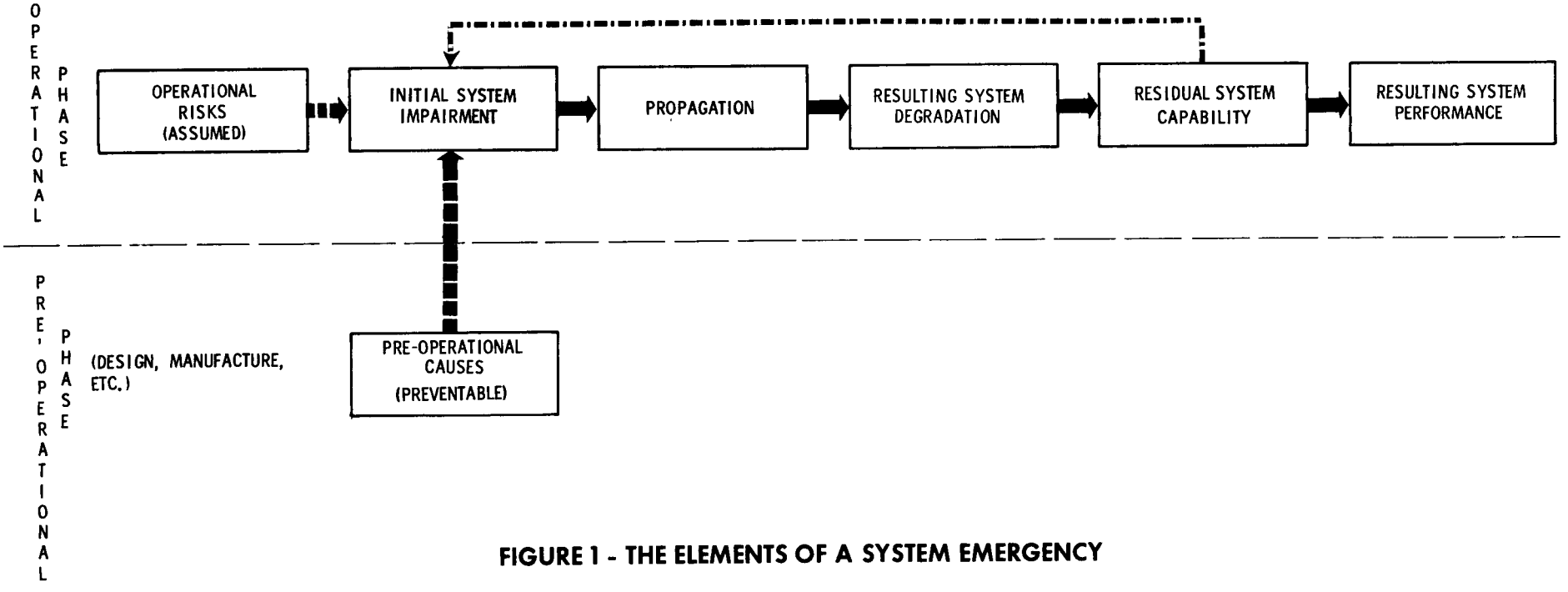

FIGURE 1 - THE ELEMENTS OF A SYSTEM EMERGENCY

MISSION PERIOD

MISSION PERIOD RISKS

1. UNKNOWN OR UNEXPECTED EXTERNAL STRESS. ENVIRONMENT OR PHENOMENON THAT MAY INJURE THE CREW OR CAUSE COMPONENT DAMAGE.
2. "EXPECTED" LOW PROBABILITY EVENT OR FAILURE.
3. NON-PREDICTABLE DISEASE OR DISORDER.
4. UNFORESEEN ENEMY ACTS AIMED AT DESTROYING THE MISSION OR A CRITICAL FUNCTION.
5. "ACT OF GOD" CATASTROPHE*

*E.G., IMPACT WITH LARGE METEOR. SUCH CATASTROPHES COULD CAUSE IMMEDIATE CREW LOSS.

(HAZARDS)

INITIAL IMPAIRMENT
(TRIGGER)

1. COMPONENT FAILURE*
2. CREW OR GROUND PERSONNEL ERROR
3. CREW IMPAIRMENT

* INCLUDES THE INITIAL EFFECT OF AN EQUIPMENT OR SOFTWARE DEFECT

PROPAGATION

1. NONE - IMPAIRMENT CONTAINED.
2. INTERNALLY GENERATED STRESSES THAT PROGRESSIVELY IMPAIR THE EQUIPMENT.
3. EXTERNALLY IMPOSED STRESSES THAT PROGRESSIVELY IMPAIR THE EQUIPMENT.
4. INTERNALLY GENERATED STRESSES THAT PROGRESSIVELY IMPAIR THE CREW
5. EXTERNALLY IMPOSED STRESSES THAT PROGRESSIVELY IMPAIR THE CREW
6. DIVERGENCE FROM MISSION PLAN OR BUDGET.

(HAZARDS)

EFFECT ON CREW AND EQUIPMENT*

CREW
- A. UNIMPAIRED
- B. MODERATLEY IMPAIRED
- C. SEVERELY IMPAIRED
- D. DECEASED OR DYING

EQUIPMENT (PRIME VEHICLE & GROUND SUPPORT)
1. UNIMPAIRED
2. MINOR IMPAIREMENT OR DEGRADED RELIABILITY
3. MAJOR IMPAIRMENT
4. DESTROYED

* BASED ON CONDITIONS AFTER PROPAGATION HAS STOPPED OR STABILIZED AND AVAILABLE MEDICAL AND REPAIR CAPABILITIES HAVE BEEN UTILIZED.

MISSION PROGRESSION

VIABLE
1. CONTINUE MISSION
2. MODIFY MISSION
3. ABORT MISSION
4. ESCAPE OR AWAIT RESCUE

NON-VIABLE
5. MAROONED
6. AWAIT IMMINENT DESTRUCTION AND/OR DEATH
7. NONE-CREW AND/OR VEHICLE DESTROYED

END RESULT*

CREW
- A. RETURNS SAFE
- B. RETURNS IMPAIRED
- C. LOST

MISSION
1. OBJECTIVE(S) ACCOMPLISHED
2. OBJECTIVE(S) PARTIALLY ACCOMPLISHED
3. OBJECTIVE(S) NOT ACCOMPLISHED

*INCLUDES RESCUE MISSION, IF ANY

PRE-MISSION PERIOD

PRE-MISSION PERIOD CAUSES
(PREVENTABLE)

1. INADEQUATE EQUIPMENT DESIGN - DOES NOT MEET PERFORMANCE OR RELIABILITY REQUIREMENTS IN KNOWN OR PREDICTABLE MISSION ENVIRONMENT(S).
2. INADEQUATE MISSION PLANNING AND PROCEDURES.
3. INADEQUATE PROTECTION AGAINST DAMAGING OR INJURIOUS INTERACTIONS BETWEEN EQUIPMENT AND CREW.
4. INADEQUATE OPERATIONAL MAN-MACHINE INTERFACES.
5. IMPROPER OR INADEQUATE MANUFACTURING, HANDLING, TESTING OR INSPECTION.
6. INADEQUATE SELECTION AND TRAINING OF PERSONNEL.

(HAZARDS)

FIGURE 2 - THE ELEMENTS OF A MANNED SPACE FLIGHT EMERGENCY

TEST PERIOD

TEST PERIOD RISK

1. PREVIOUSLY UNKNOWN OR UNEXPECTED EXTERNAL STRESS, ENVIRONMENT OR PHENOMENON THAT MAY INJURE THE CREW OR CAUSE COMPONENT DAMAGE.
2. "EXPECTED" LOW PROBABILITY EVENT OR FAILURE.
3. "ACT OF GOD" CATASTROPHE*

*E.G., SUCH CATASTROPHES COULD CAUSE IMMEDIATE CREW LOSS.

(HAZARDS)

INITIAL IMPAIRMENT
(TRIGGER)

1. COMPONENT FAILURE*
2. PERSONNEL ERROR
3. PERSONNEL IMPAIRMENT

* INCLUDES THE INITIAL EFFECT OF AN EQUIPMENT OR SOFTWARE DEFECT

PROPAGATION

1. NONE - IMPAIRMENT CONTAINED.
2. INTERNALLY GENERATED STRESSES THAT PROGRESSIVELY IMPAIR THE EQUIPMENT.
3. EXTERNALLY IMPOSED STRESSES THAT PROGRESSIVELY IMPAIR THE EQUIPMENT.
4. INTERNALLY GENERATED STRESSES THAT PROGRESSIVELY IMPAIR THE PERSONNEL.
5. EXTERNALLY GENERATED STRESSES THAT PROGRESSIVELY IMPAIR THE PERSONNEL.
6. DIVERGENCE FROM TEST PLAN.

(HAZARDS)

EFFECT ON PERSONNEL AND EQUIPMENT

PERSONNEL

- A. UNIMPAIRED
- B. IMPAIRED
- C. SEVERELY IMPAIRED
- D. DECEASED OR DYING

EQUIPMENT

1. UNIMPAIRED
2. MINOR IMPAIRMENT OR DEGRADED RELIABILITY
3. MAJOR FUNCTIONAL IMPAIRMENT
4. DESTROYED

TEST PROGRESSION

VIABLE

1. CONTINUE TEST
2. MODIFY TEST
3. STOP TEST
4. ESCAPE OR WAIT FOR RESCUE

NON-VIABLE

6. AWAIT DELAYED DEATH
7. AWAIT IMMINENT DESTRUCTION AND/OR DEATH
8. NONE - PERSONNEL AND/OR VEHICLE DESTROYED

END RESULT *

PERSONNEL*

- A. SAFE
- B. IMPAIRED
- C. LOST

TEST

1. OBJECTIVE(S) ACCOMPLISHED
2. OBJECTIVE(S) PARTIALLY ACCOMPLISHED
3. OBJECTIVE(S) NOT ACCOMPLISHED

*INCLUDES RESCUE PERSONNEL, IF INVOLVED

PRE-TEST PERIOD

PRE-TEST PERIOD CAUSES
(PREVENTABLE)

1. INADEQUATE EQUIPMENT DESIGN - DOES NOT MEET PERFORMANCE OR RELIABILITY REQUIREMENTS IN KNOWN OR PREDICTABLE TEST ENVIRONMENT(S).
2. INADEQUATE TEST PLANNING AND PROCEDURES.
3. INADEQUATE PROTECTION AGAINST DAMAGING OR INJURIOUS INTERACTIONS BETWEEN EQUIPMENT AND PERSONNEL.
4. INADEQUATE OPERATIONAL MAN-MACHINE INTERFACES.
5. IMPROPER OR INADEQUATE MANUFACTURING, HANDLING, TESTING OR INSPECTION.
6. INADEQUATE SELECTION AND TRAINING OF PERSONNEL.

(HAZARDS)

FIGURE 3 - THE ELEMENTS OF A MANNED TEST EMERGENCY

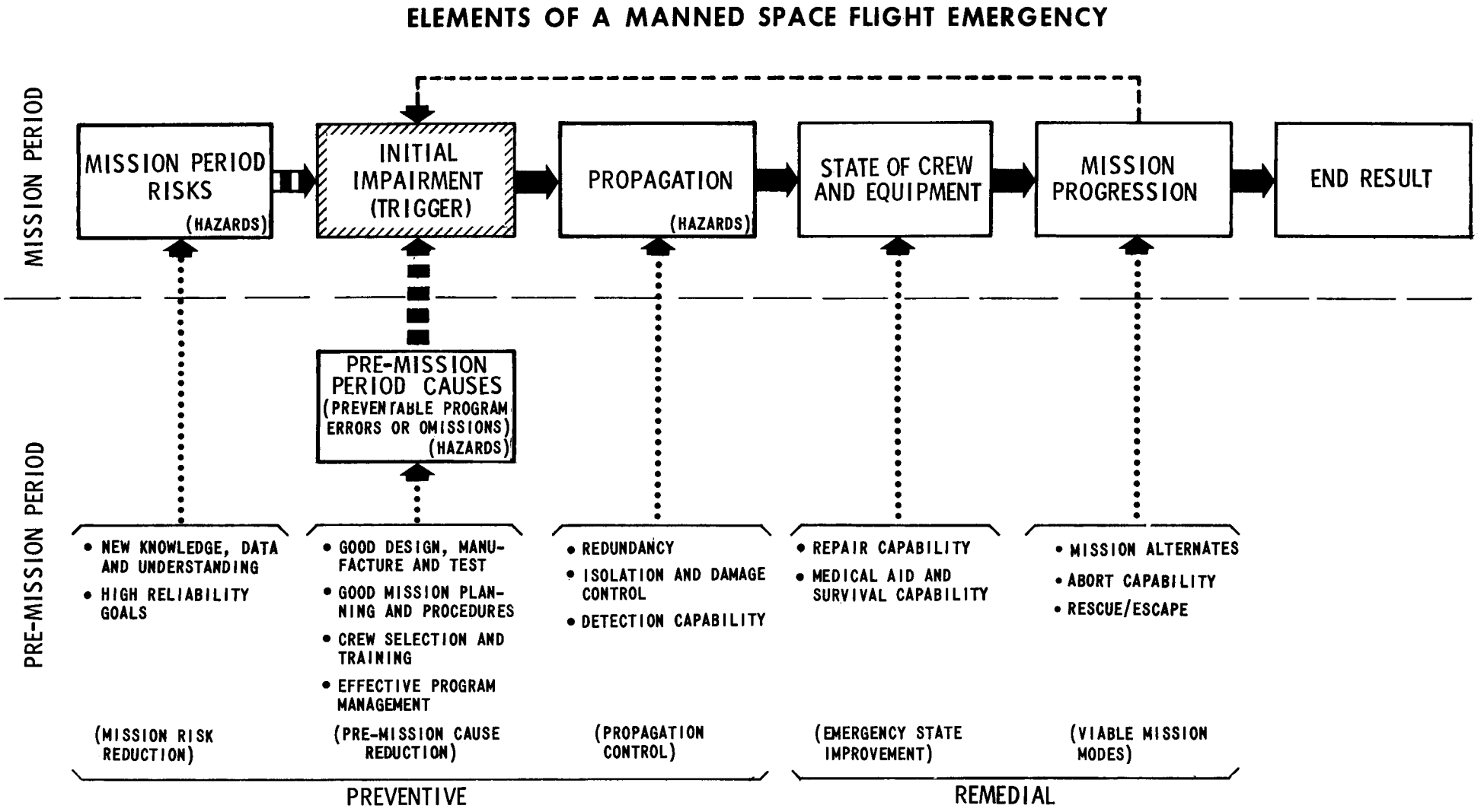

FIGURE 4 - SPACE FLIGHT EMERGENCIES AND SAFETY MEASURES

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TABLE 1

USAF (AF)

ACCELERATION
CONTAMINATION
CORROSION
DISSOCIATION, CHEMICAL
ELECTRICAL
EXPLOSION
FIRE
HEAT & TEMPERATURE
LEAKAGE
MOISTURE
OXIDATION
PRESSURE
RADIATION
REPLACEMENT, CHEMICAL
SHOCK
STRESS CONCENTRATIONS
STRESS REVERSALS
STRUCTURAL DAMAGE OR FAILURE
TOXICITY
VIBRATION AND NOISE
WEATHER AND ENVIRONMENT

TEAGUE (T)

POWER FAILURE
LIFE SUPPORT FAILURE
CONTROL SYSTEM FAILURE
PROPULSION FAILURE
RCS FAILURE
EVA HAZARD
RADIATION
METEOROID
COLLISION
ACTIVITY INDUCED EMERGENCY
OPERATIONAL ERROR
ILLNESS
FIRE/EXPLOSION

GE

ACCELERATION
AERODYNAMIC LOADS
AERODYNAMIC HEATING
AEROEMBOLISM
ANOXIA
ATTITUDE CONTROL LOSS
BASE HEATING
CHEMICAL INJURY
COLLISION
CONTAMINATION
CORROSION
DEHYDRATION
DISSOCIATION, CHEMICAL
DROWNING
ELECTRICAL-INADVERTENT ACTIVATION
ELECTRICAL-POWER SOURCE FAILURE
ELECTRICAL-THERMAL
ELECTRICAL SHOCK
ELECTROMAGNETIC RADIATION
EXPLOSION
EXPOSURE
FIRE
HUMAN ERROR
LEAKAGE
MOISTURE
NAUSEA
OXIDATION (OTHER THAN AIR)
PRESSURE
PROPULSION FAILURE
RADIATION
REPLACEMENT, CHEMICAL
SHOCK AND IMPACT
SPACE DEBRIS
STARVATION
STRESS CONCENTRATION
STRESS REVERSAL
STRUCTURAL FAILURE
TEMPERATURE EXTREME
TOXICITY
TUMBLING
VIBRATION AND NOISE
WEATHER AND ENVIRONMENT
STAGING FAILURE

AEROSPACE (A)

FIRE
FRAGMENTATION
TUMBLING
CABIN RUPTURE
COLLISION
SMOKE
PERSONNEL INJURY
LOSS OF LIFE SUPPORT
PROPULSION FAILURE
CAN'T REENTER
ILLNESS
OFF-COURSE

RAND (R)

THREATS
- METABOLIC DEPRIVATION
- EXCESSIVE PHYS. STRESS
- INJURY

CAUSES
- IMPAIRED EQUIPMENT OR CREW
- EQUIPMENT FAILURE
- PERSONNEL ERROR
- ENVIRONMENTAL HAZARD (PERSONNEL BREAKDOWN)

TABLE 2

ITEM	CATEGORY AND IDENTIFIER				
	MISSION PERIOD RISKS	INITIAL IMPAIR-MENT	PRE-MISSION PERIOD CAUSES	PROPA-GATION	CREW AND EQUIPMENT
ACCELERATIONS			AF GE	AF GE	
ACTIVITY INDUCED EMERGENCY	T		T		
AERODYNAMIC LOADS			GE	GE	
AERODYNAMIC HEATING			GE		
AEROEMBOLISM				GE	
ANOXIA				GE	
ATTITUDE CONTROL LOSS					GE
BASE HEATING			GE	GE	
CAN'T TAKE OFF FROM LUNAR SURFACE*					
CAN'T REENTER EARTH ATMOSPHERE*					
CABIN RUPTURE				A	A
CHEMICAL INJURY				GE	
CONTAMINATION			GE	GE	
CONTROL SYSTEM FAILURE					T
COLLISION	GE A			GE A	
CORROSION			GE AF	GE AF	
DEHYDRATION				GE	
DISSOCIATION, CHEMICAL				GE AF	
DROWNING					GE
ELECTRICAL-INADVERTENT ACTIVATION		GE			

* CLASSIFIED AS MISSION PROGRESSION (IDENTIFIER R)

TABLE 2 (CONTINUED)

ITEM	CATEGORY AND IDENTIFIER				
	MISSION PERIOD RISKS	INITIAL IMPAIR-MENT	PRE-MISSION PERIOD CAUSES	PROPA-GATION	EFFECT ON CREW AND EQUIPMENT
ELECTRICAL-POWER SOURCE FAILURE					GE T
ELECTRICAL SHOCK			GE		
ELECTRICAL-THERMAL			GE		
ENVIRONMENTAL HAZARD	R AF GE		R AF GE		
EQUIPMENT FAILURE					R
EVA HAZARD	T		T		
EXPLOSION				AF GE T	
EXPOSURE				GE	
FIRE				AF GE T	
FRAGMENTATION				A	
HEAT & TEMPERATURE				AF	
IMPACT			GE	GE	
LEAKAGE				AF GE	
LIFE SUPPORT SYSTEM FAILURE					R T A
METABOLIC DEPRIVATION				R	R
METEOROID	T				
MOISTURE			AF GE		
NAUSEA				GE	
OXIDATION			AF GE		
OFF COURSE				A	
PERSONNEL ERROR		GE R T			
PERSONNEL ILLNESS	R T A			R T A	
PERSONNEL INJURY	R A			R A	

TABLE 2 (CONTINUED)

ITEM	CATEGORY AND IDENTIFIER				
	MISSION PERIOD RISKS	INITIAL IMPAIR-MENT	PRE-MISSION PERIOD CAUSES	PROPA-GATION	EFFECT ON CREW AND EQUIPMENT
PRESSURE				AF GE	
PROPULSION FAILURE					GE T A
RADIATION	AF GE T		AF GE T	AF GE T	
REPLACEMENT, CHEMICAL			AF GE		
RCS FAILURE					T
SHOCK			AF GE	AF GE	
SMOKE				A	
SPACE DEBRIS	GE				
STAGING FAILURE				GE	GE
STARVATION				A	
STRESS CONCENTRATIONS			AF GE		
STRESS REVERSALS			AF GE		
STRUCTURAL FAILURE				AF GE R	
TEMPERATURE EXTREME				GE	
TOXICITY				AF GE	
TUMBLING*					
UNDESIRED PROLONGATIONS OF MISSION**					
VIBRATION AND NOISE			AF GE	AF GE	
WEATHER	AF GE		AF GE		

*CLASSIFIED AS MISSION PROGRESSION (IDENTIFIERS GE AND A)

**CLASSIFIED AS MISSION PROGRESSION (IDENTIFIER R)

Table 3

CHECKLIST

Category - Mission Period Risks (Hazards)

Description - Mission hazards which are accepted as unavoidable given existing art and knowledge. These may be grouped as follows:

1. Unknown or unexpected external stresses, environment, or phenomenon.
2. "Expected" low probability events or failures.
3. Non-predictable diseases or disorders.
4. Unforeseen enemy acts aimed at destroying the mission or a critical function.
5. "Act of God" catastrophies.

Checklist Usage (Primary) - Agency Management, Program Management, Mission Planning

Identified Hazards By Group	Identifier	Remarks
1		
Environmental Hazard	R AF GE	Non-predictable
- Meteoroid	T	"
- Radiation	AF GE T	"
- Weather	AF GE	"
EVA Hazard	T	"
Activity Induced Emergency	T	"
2		
Low Statistical Probability Event	*	e.g., failure of a high rel. resistor
3		
Personnel Illness	R T A	Non-predictable
Personnel Injury	R A	"
4		
Sabotage - Jamming	*	"
Overt Act of War	*	"
5		
Collision	GE A	"
Space Debris (Collision)	GE	"

* Added by the writer

Table 4

CHECKLIST

Category - Pre-Mission Period Causes (Hazards)

Description - Human errors of omission or commission that cause stresses, environments, defects, and operational difficulties that lead to an initial impairment.

1. Inadequate equipment design - does not meet performance or reliability requirements in known or predictable mission environment(s).
2. Inadequate mission planning and procedures.
3. Inadequate protection against damaging or injurious interactions between equipment and crew.
4. Inadequate operational man-machine interfaces.
5. Improper or inadequate manufacturing, handling, testing, or inspection.
6. Inadequate selection and training of personnel.

Checklist Usage (Primary) - Program Management, Design, Mission Planning, Safety Engineering

Identified Hazards By Group 1	Identifier	Remarks
Accelerations	AF GE	Preventable
Aerodynamic Loads	GE	"
Aerodynamic Heating	GE	"
Base Heating	GE	"
Corrosion	GE AF	"
Environmental Hazard	R AF GE	"
EVA Hazard	T	"
Moisture	AF GE	"
Oxidation	AF GE	"
Radiation	AF GE T	"
Replacement, Chemical	AF GE	"
Stress Concentrations	AF GE	"
Stress Reversals	AF GE	"
Vibration and Noise	AF GE	"
Weather	GE	"

Table 4 (continued)

Identified Hazards By Group	Identifier	Remarks
2		
Crew Task Load too High	*	Preventable
Unclear Procedures	AF	"
3		
Electrical Shock	GE	"
Electrical-Thermal	GE	"
Impact	GE	"
Shock	AF GE	"
Activity Induced Emergency	T	"
4		
Crewmen Unable to Properly Monitor Indicators because of Placement	AF	"
5		
Contamination	GE	"
Corrosion	GE AF	"
Mechanical Damage to Component or Assembly	*	"
Acceptance of Off-tolerance Component (Usually because of delivery date)	*	
Moisture	AF GE	"
6		
Crewman not Psychologically Suited for Mission	*	"
Crewman Training Incomplete	*	"

*Added by the writer

Table 5

CHECKLIST

Category - Initial Impairment (Trigger)

Description - The failure or event is traceable to a Mission Risk or an Underlying Cause, which triggers an emergency. Groups are:

1. Component Failure
2. Crew or Ground Personnel Error
3. Crew Impairment

Checklist Usage - Design, Mission Planning (Primary)

Identified Triggers By Group	Identifier	Remarks
1		
Failure of one or more components - transistor, resistor, bearing, seal, gear, etc.	*	
2		
Personnel Error	GE R T	
Electrical-Inadvertent Activation	GE	
3		
Crew is unable to perform necessary functions because of injury or illness of one or more crewmen	R	

*Added by the writer

Table 6

CHECKLIST

Category - Propagation (Hazards)

Description - The process through which initial impairment, if not contained, progressively impairs the crew, equipment of a planned mission. The hazards or stresses in this category may be grouped as follows:

1. None - Impairment contained.
2. Internally generated stresses that progressively impair the equipment.
3. Externally imposed stresses that progressively impair the equipment.
4. Internally generated stresses that progressively impair the crew.
5. Externally imposed stresses that progressively impair the crew.
6. Divergence from mission plan or budget.

Checklist Usage - (Primary) System Design, Safety Engineering, Mission Planning

Identified Hazards By Group	Identifier	Remarks
1		
Impairment Remains Localized		
2		
Base Heating	GE	
Corrosion	GE AF	
Dissociation, Chemical	GE AF	
Electrical Overload	*	
Explosion	AF GE T	
Fire	AF GE T	
Heat & Temperature	AF	
Leakage	AF GE	
Staging Failure	GE	
Structural Failure	GE	
Temperature Extreme	AF GE R	

* Added by the writer

Table 6 (continued)

Identified Hazards By Group	Identifier	Remarks
3		
Aerodynamic Loads	GE	
Accelerations	AF GE	
Cabin Rupture	A	
Collision	GE A	
Corrosion	GE AF	
Dissociation, Chemical	GE AF	
Explosion	AF GE T	
Fire	AF GE T	
Fragmentation	A	
Heat & Temperature	AF	
Impact	GE	
Leakage	AF GE	
Pressure	AF GE	
Radiation	AF GE T	
Structural Failure	GE	
Temperature Extreme	AF GE R	
Vibration and Noise	AF GE	
4		
Nausea	GE	
Personnel Illness	R T A	
5		
Accelerations	AF GE	
Chemical Injury	GE	
Collision	GE A	
Explosion	GE	
Exposure	GE	
Fire	AF GE T	
Fragmentation	A	
Heat & Temperature	AF	
Impact	GE	
Leakage	AF GE	
Pressure	AF GE	
Radiation	AF GE T	
Smoke	AF GE	
Temperature	AF GE R	

Table 7

CHECKLIST

Category - State of Crew and Equipment

Description - The state of crew and equipment after propagation has stopped or stabilized and available medical and repair capabilities have been utilized. Crew and equipment may be classified as follows:

Crew

a. Unimpaired
b. Moderately impaired
c. Severely impaired
d. Deceased or dying

Equipment (Prime Vehicle & Ground Support)

1. Unimpaired
2. Minor impairment or degraded reliability
3. Major impairment
4. Destroyed

Checklist Usage (Primary) - Agency Management, Program Management, Mission Plannning

Identified State By Group	Identifier	Remarks
a		
No degradation of capability		
b		
Dehydration	GE	
Moderate Injury	*	
c		
Aeroembolism	GE	
Blindness	*	
d		
Anoxia	GE	
Starvation	GE	
Drowning	GE	

*Added by the writer

Table 7 (continued)

Identified State By Group	Identifier	Remarks
1		
No degradation of capability		
2		
Cabin Windows partially fogged	*	
Failure of redundant item	*	
3		
Attitude control loss	GE	
Cabin rupture	A	
Control system failure	T	
Electrical power source failure	GE T	
Life support system failure	R T A	
Propulsion failure	GE T A	
RCS failure	T	
Staging failure	GE	
4		
Equipment is totally useless		

* Added by the writer

ATTACHMENT A

Manned Space Flight Program Elements

1. Agency Management - An individual or organization concerned with a multiplicity of space programs and their interrelationships.

2. Program Management - The individual or organization charged with the successful completion of a single space program.

3. Space Vehicle Design - The individual or organization charged with the design of a complete space vehicle.

4. Stage or Module Design - The individual or organization charged with the design of a launch vehicle stage or a spacecraft module.

5. System Design - The individual or organization responsible for the design of a launch vehicle of spacecraft system, such as an electrical power system.

6. Component Design - The individual or organization charged with the design of a small unit or assemblage of parts, such as an electronic amplifier or a control valve.

7. Mission Planning - The individual or organization charged with planning of space missions, procedures, and contingency operations.

8. Safety Engineering - The individual or organization charged with an overview of the safety aspects of a program. Safety Engineering may practice the "System Safety" discipline.

ATTACHMENT B

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